Sampling and sensor capabilities in long-term borehole observatories

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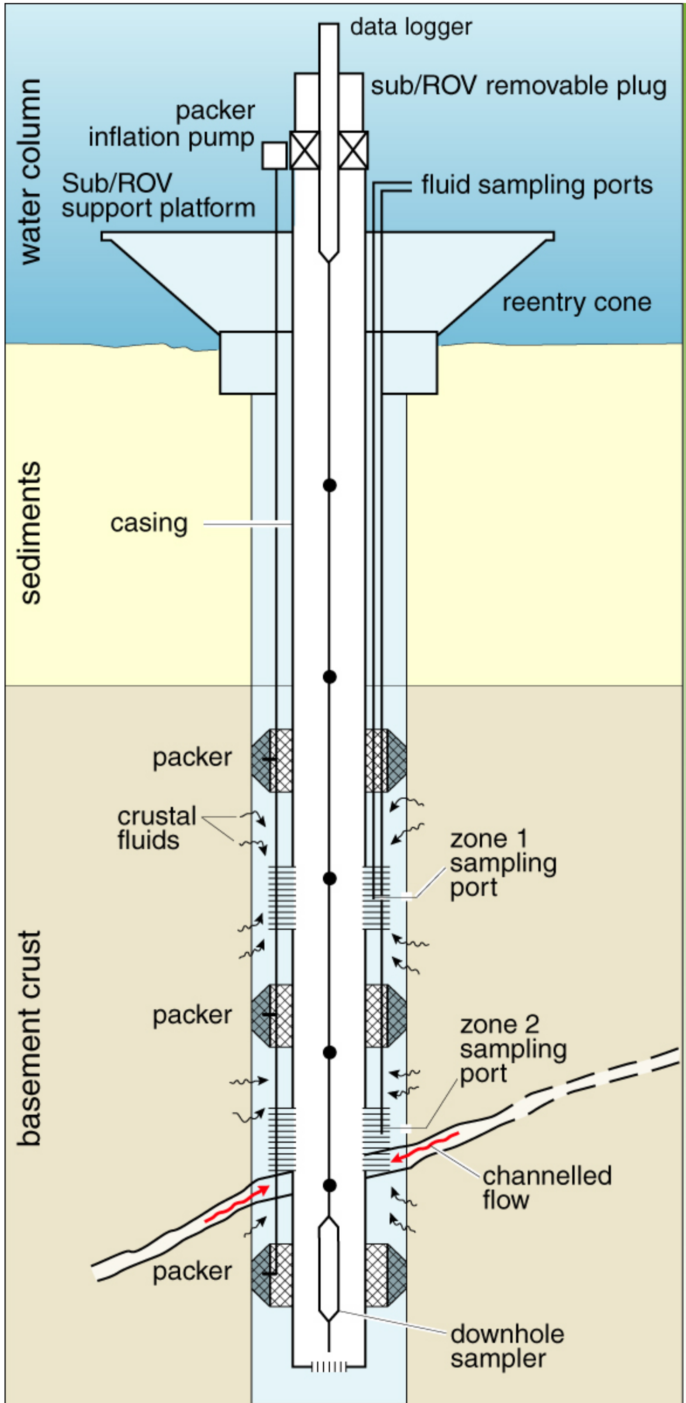


Graphic courtesy J. Cowen, B. Glazer

"CORK"s = Subsurface Borehole Observatories

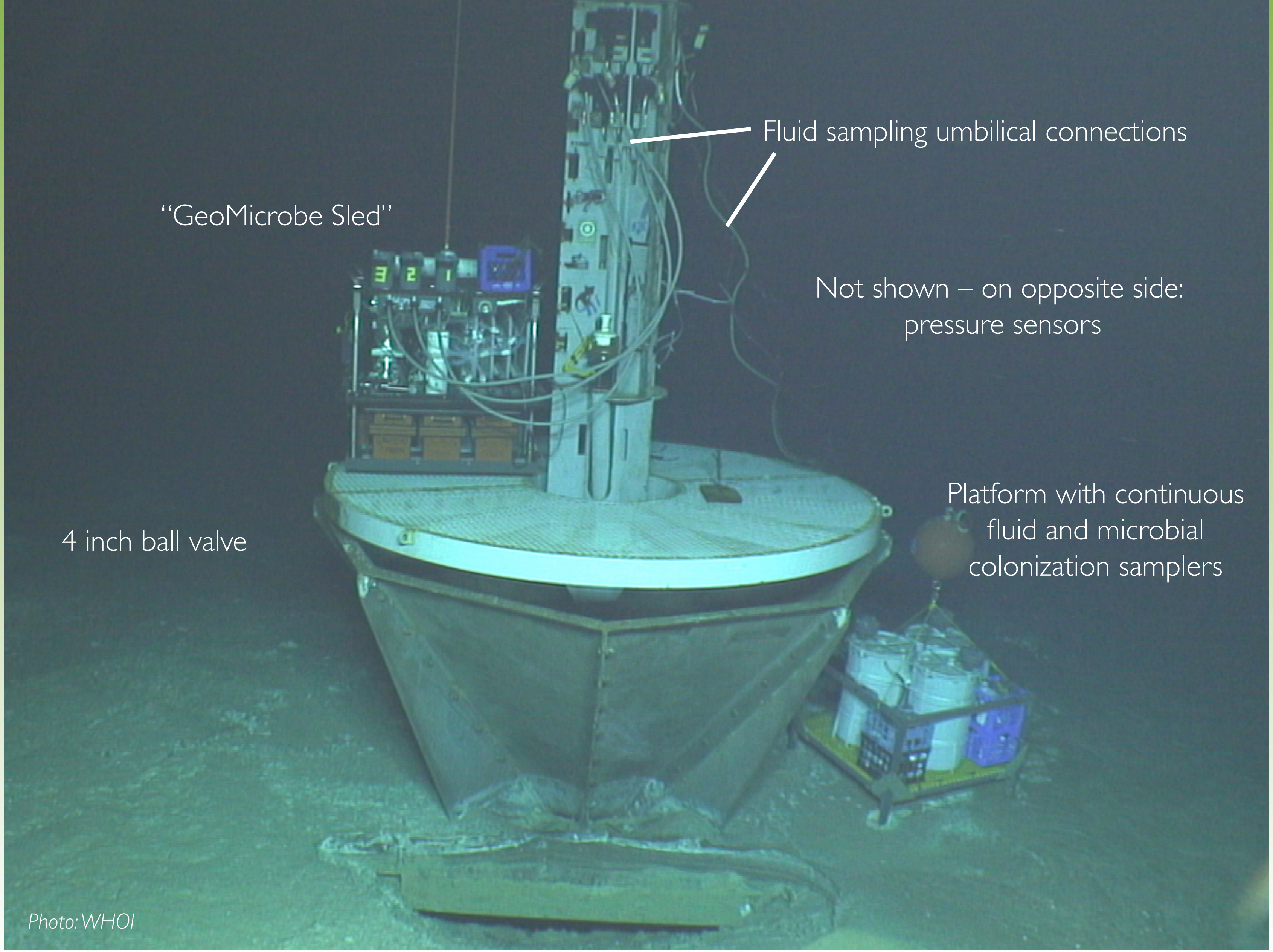
BACKGROUND READING:

Becker and Davis, 2005 (IODP X301 volume)
Fisher et al., 2005 (IODP X301 volume)
Fisher et al., 2011 (IODP X327 volume)
Wheat et al. 2011 (IODP X327 volume)

Newest CORKs – X327 – Juan de Fuca

http://www.youtube.com/watch?feature=player_embedded&v=LxFt44sKFXE#!

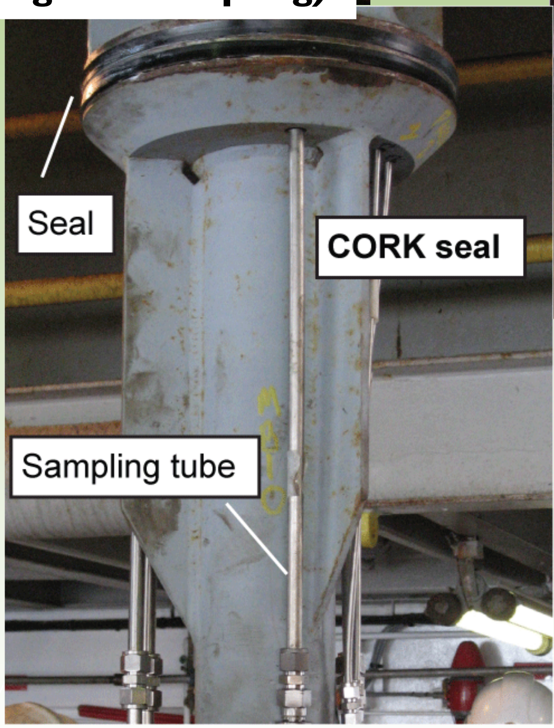
Newest CORKs – X336 – North Pond

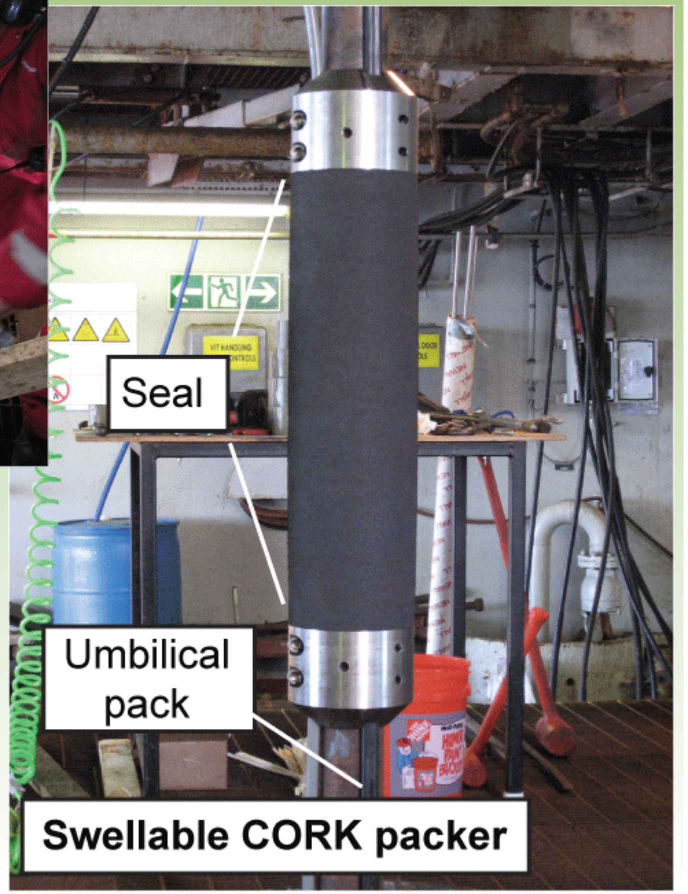


Newest CORKs – X327 – Juan de Fuca

Components for sealing, sampling borehole for geochem & microbio

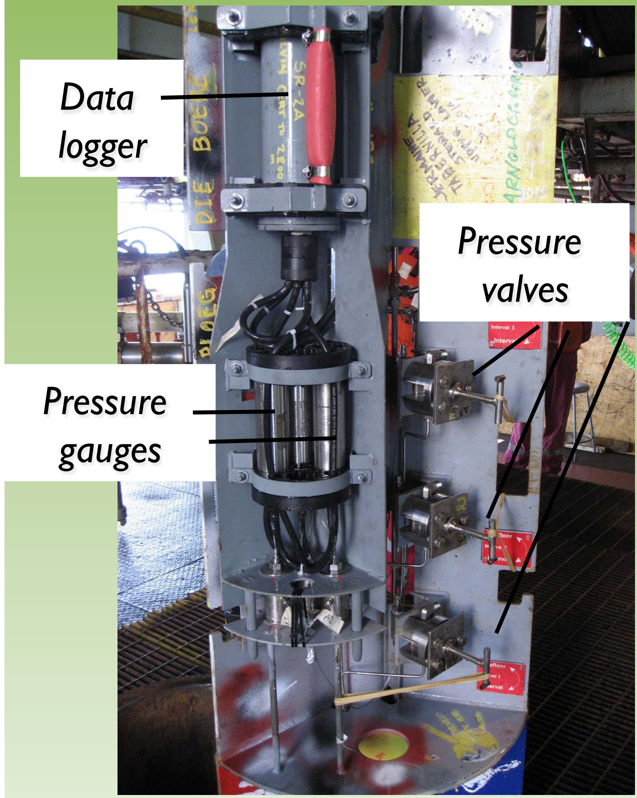
Fisher et al. 2011 X327 volume
Photos: Andy Fisher





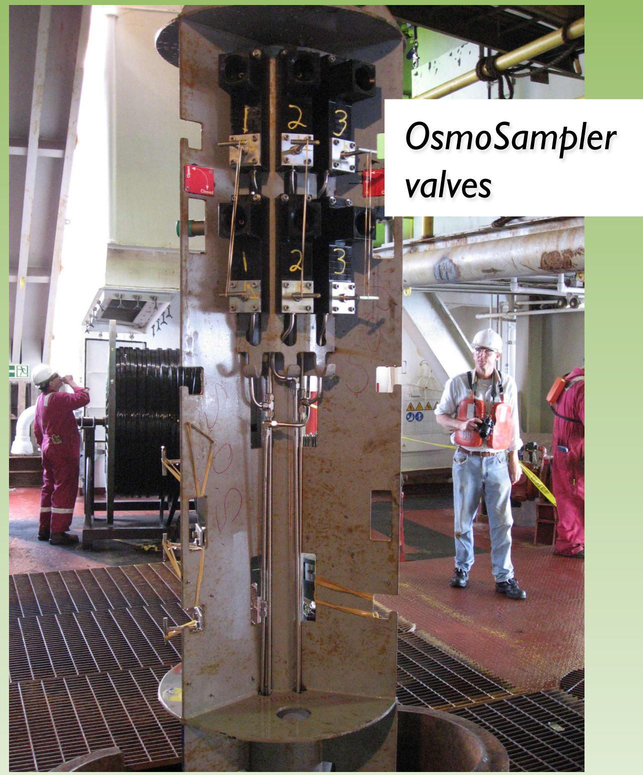
Newest CORKs – X327 – Juan de Fuca

Three bays for three kinds of sampling & monitoring



Multilevel Pressure Monitoring

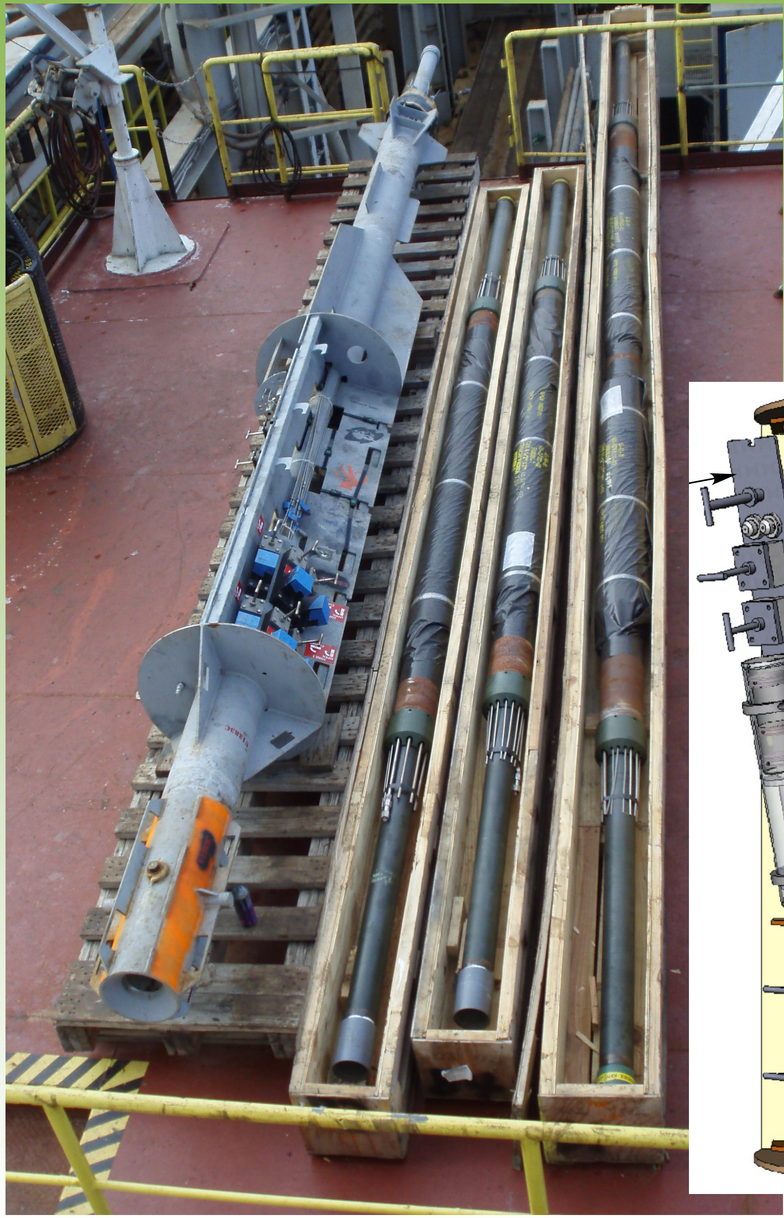
Fluid sampling (Teflon lined umbilicals) by GeoMicrobe Sled & Free flow valve

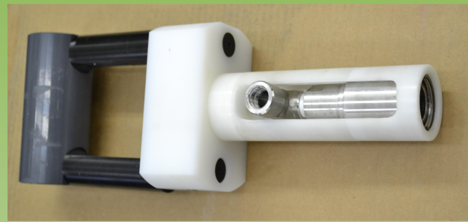


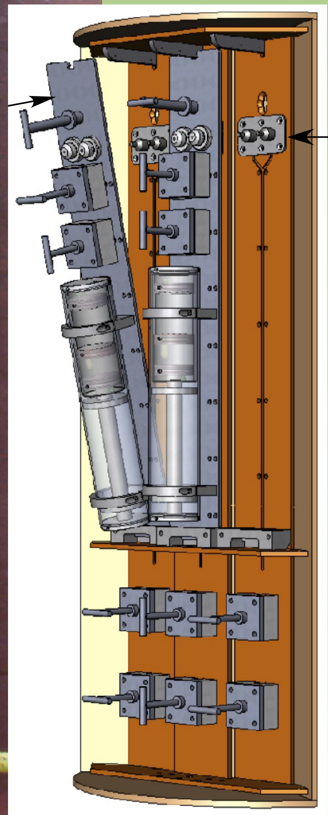
Fluid sampling for microbiology and colonization experiments

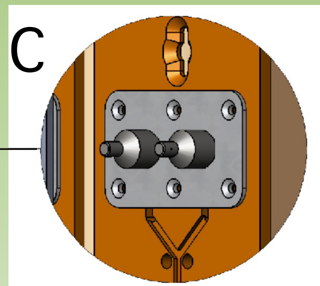
Fisher et al. 2011 X327 volume
Photos: Andy Fisher

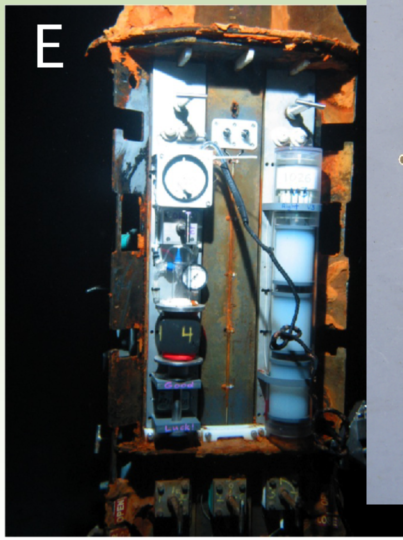
Various ways to connect OsmoSamplers at the seafloor

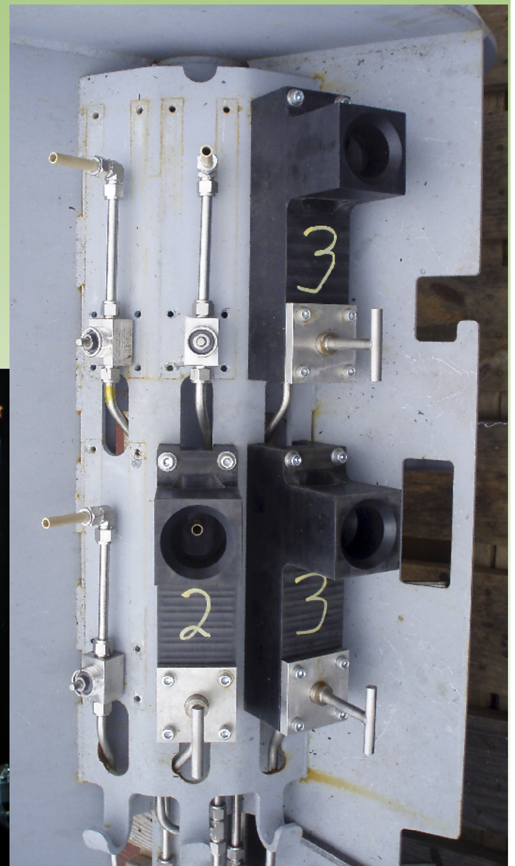












Fluid sampling with GeoMicrobe Sled at seafloor

Fluids for electrochemistry, temperature, pH, microbiology

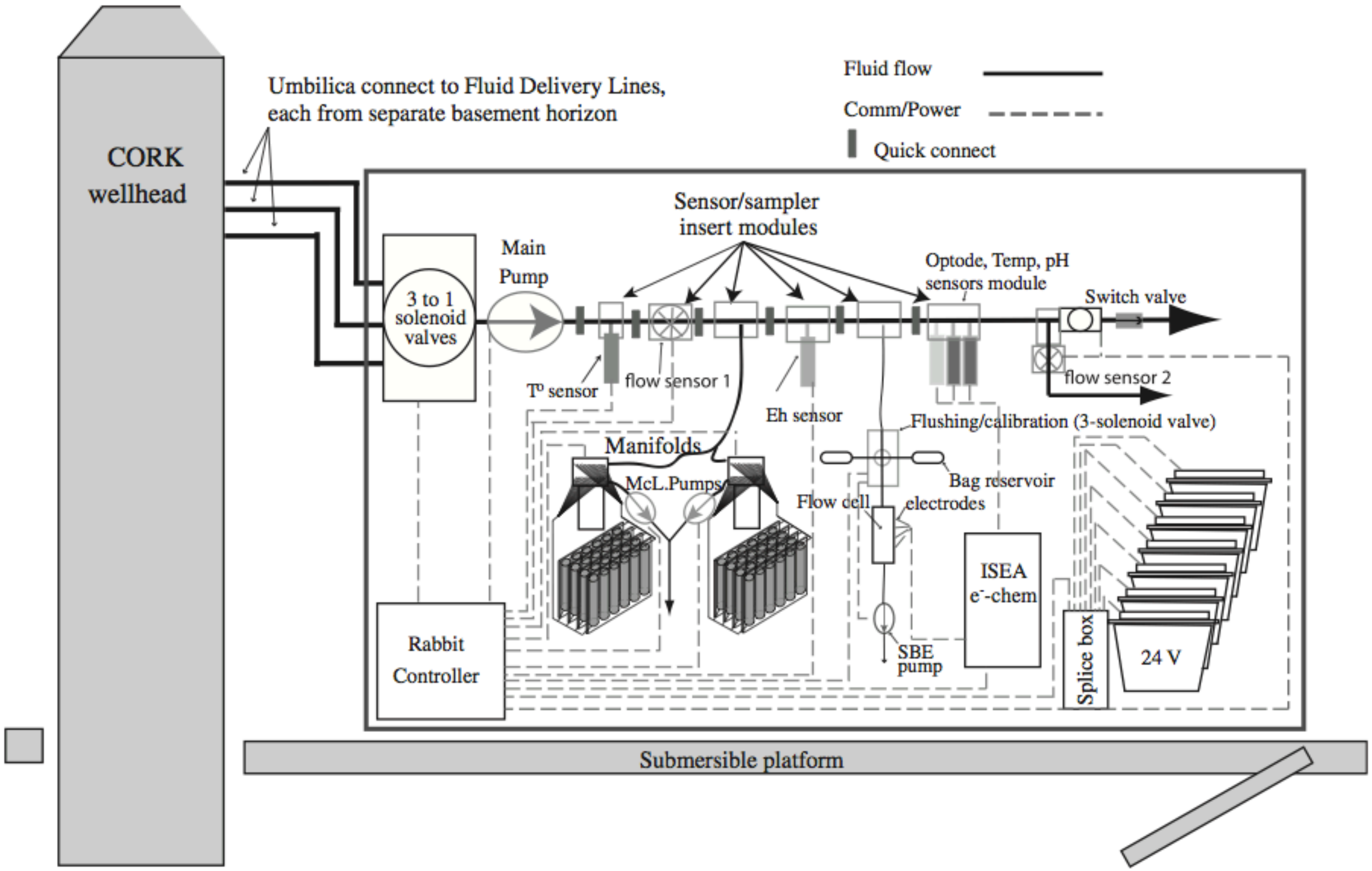


Fig. 2. Cartoon illustrating the fluid flow and communication/power pathways of the newest generation GeoMICROBE sled. Solid black lines represent fluid flow pathways and dashed red lines the power and communications cabling.

Cowen et al. Deep Sea Research 2012

Newest CORKs – X327 – Juan de Fuca

Components for sealing, sampling borehole for geochem & microbio

Electromagnetic flow sensor, repackaged for use in the deep sea, logger memory

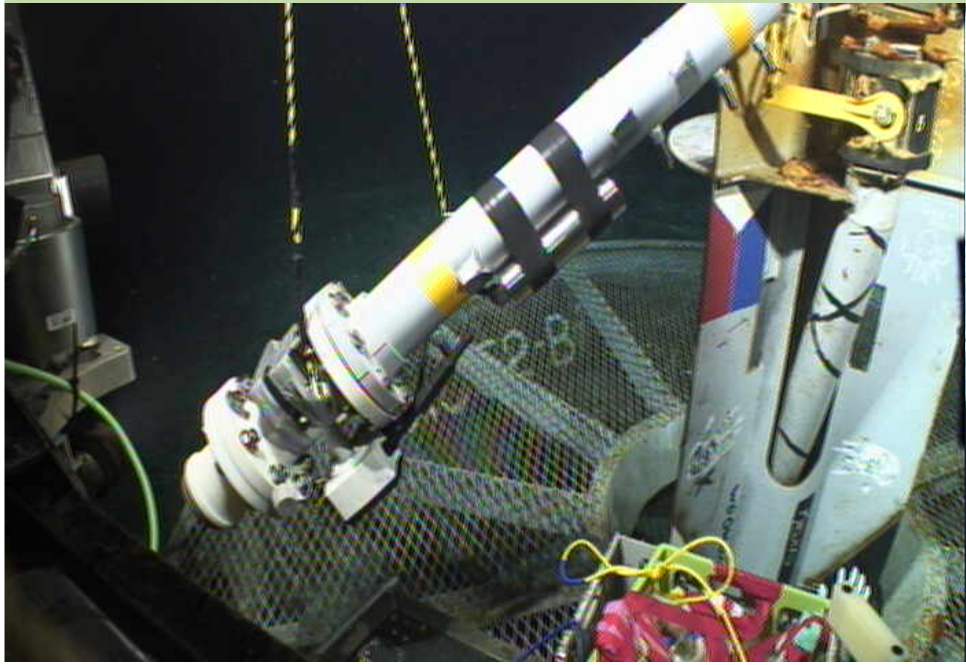
Calibrated in the lab and at sea (pump, elevator), deployed on CORK in Hole 1362B

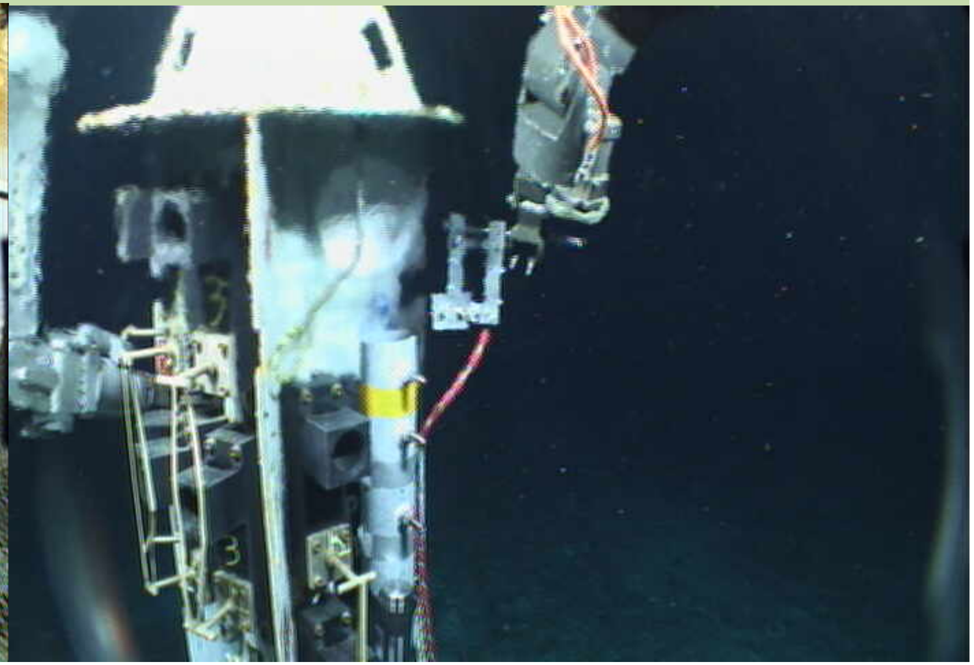
Opened valve, jet of hydrothermal fluids (i.e. shimmering water)

Measuring once per hour over a year to get flow rate

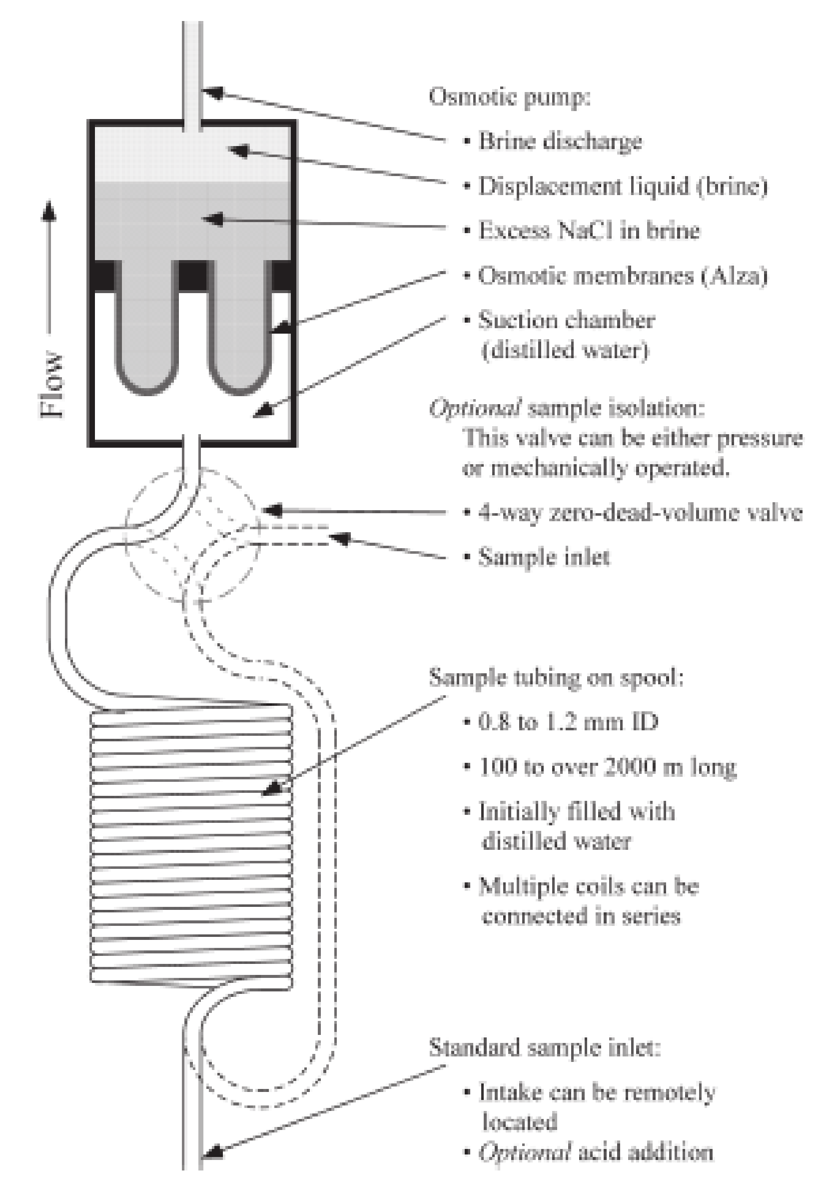
Opportunity for fluid sampling

Fisher et al. 2012 Scientific Drilling
Photos: WHOI





NO POWER Fluid sampling from CORKs



Jannasch at el 2004

"Osmopumps"

BACKGROUND READING:
Jannasch et al. 2004 Limnology & Oceanography
Wheat et al. 2011 (IODP X327 volume)
Kastner et al. 2006 (Oceanography vol 19)

Downhole OsmoSamplers

Photo Geoff Wheat

BACKGROUND READING:
Wheat et al. 2011 (IODP X327 volume)
Edwards et al. 2012 (IODP X336 volume)*
** In press*

Many varieties of OsmoSamplers

Regular (Teflon) – major/ minor ions

Acid Addition – trace metals

Copper – gases

BOSS – biological preservation

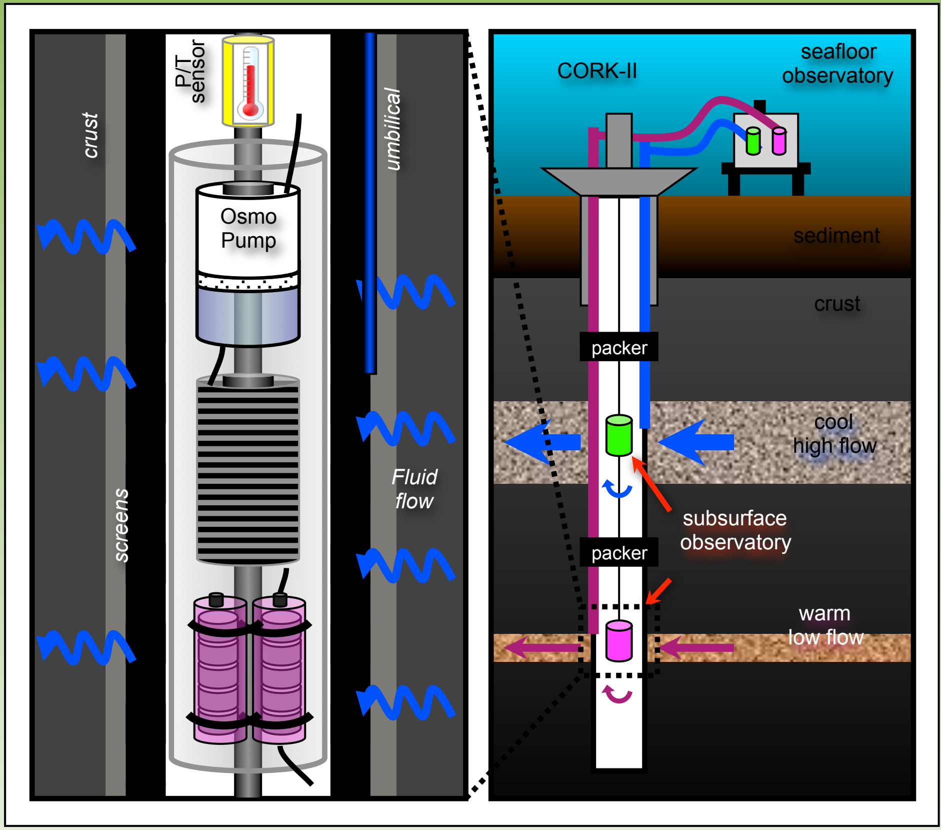
MBIO – microbial colonization experiments

Enrichment – microbial enrichment experiments

BACKGROUND READING:
Wheat et al. 2011 (IODP X327 volume)

EXAMPLE – Juan de Fuca CORKS (IODP X301/327)

Using CORKs to explore subsurface microbiology



Subsurface microbial colonization experiments combined with "OsmoSamplers" to pull fluids over substrates for microbial growth

Fisher et al., 2005; Orcutt et al. *ISME J* 2010

EXAMPLE – Juan de Fuca CORKS (IODP X301/327)

Subsurface microbial observatories

Microbial colonization experiments

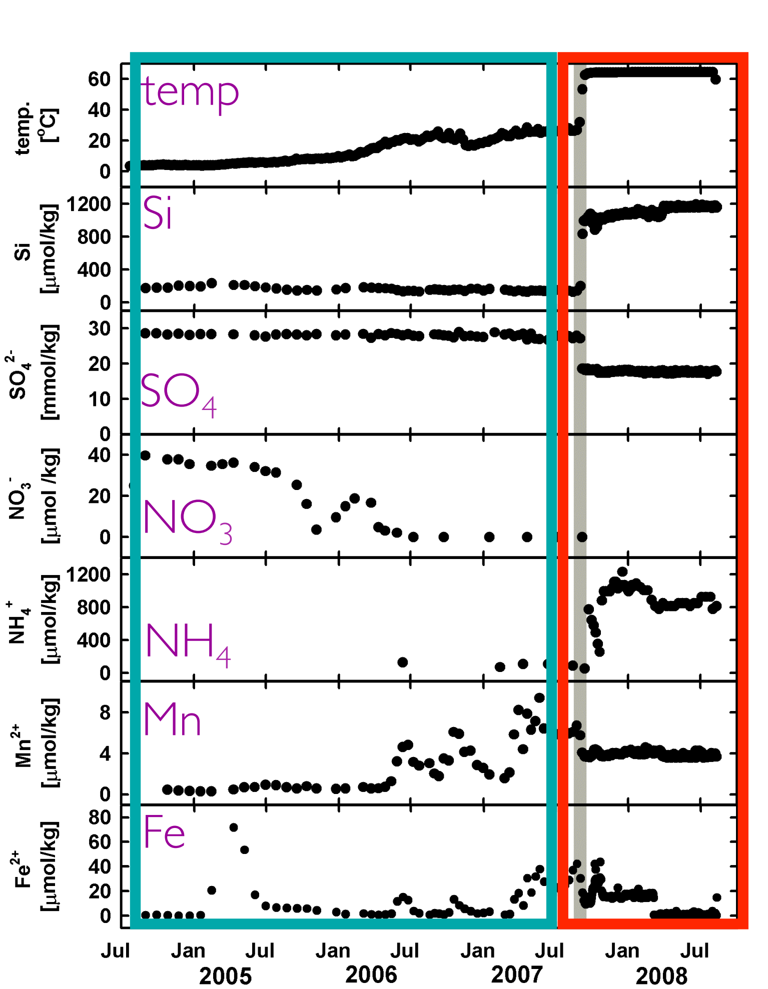
FLOCS = FLow-through Osmo Colonization System

Orcutt et al., Geomicrobiology J 2010

Connected with long-term (~5 year) chemical sensors to track changes in borehole environment

EXAMPLE – Juan de Fuca CORKS (IODP X301/327)

CORKs on the eastern Juan de Fuca Ridge flank



Continuous temperature and chemical data collection record "re-bound" of hole conditions after ~3 years

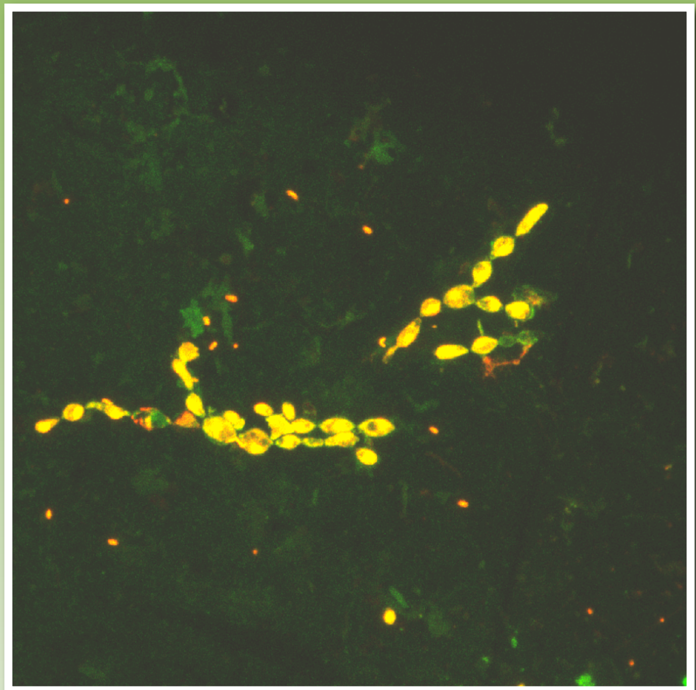
'RECHARGE' - sucking cold seawater into borehole

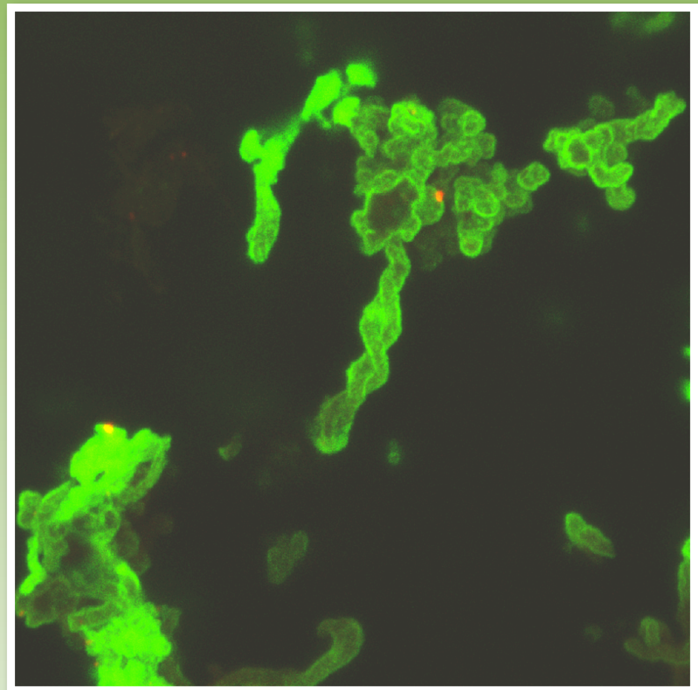
'DISCHARGE' - venting warm, reduced fluids out of crust

Orcutt et al. *ISME J* 2010;
Wheat et al. G^3 2010

EXAMPLE – Juan de Fuca CORKS (IODP X301/327)

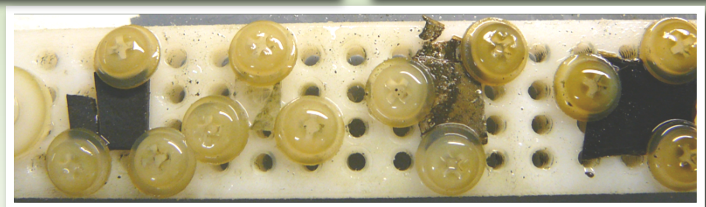
CORKs on the eastern Juan de Fuca Ridge flank





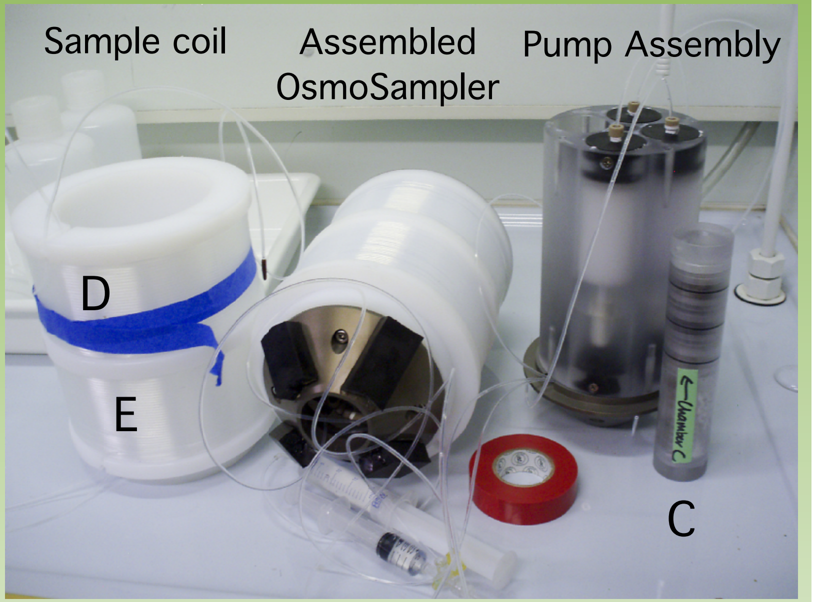
Mineral chips deployed in the subsurface for 4 years were **colonized by cells** with differing morphology

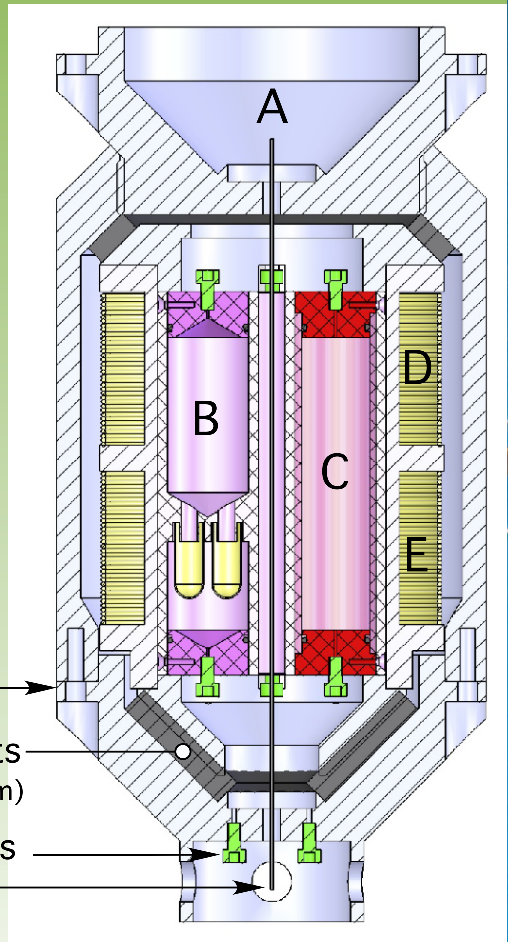
Biogenic-like **twisted stalks** also evident - indication of iron oxidizing bacteria ?



Orcutt et al. *ISME J* 2010

Many Shapes and Sizes
OsmoSamplers



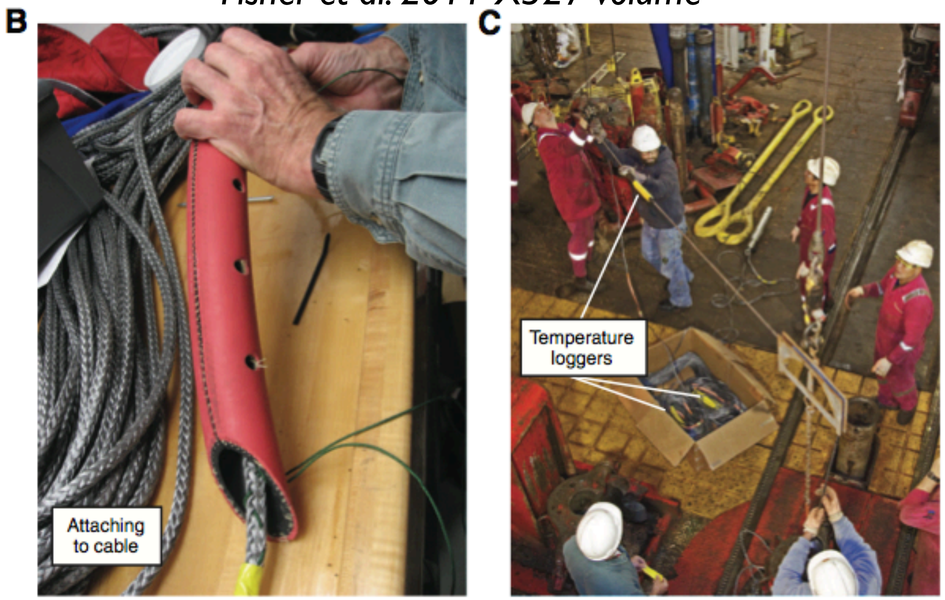


A: Housing for pressure monitor
B: Osmotic pump (1 of 3)
C: BioChamber
D: Chemistry sample coil
E: Biology sample coil

BACKGROUND READING:
Kopf et al. 2011 (IODP X332 volume)

Downhole instruments

Fisher et al. 2011 X327 volume



Edwards et al. in press X336 volume

New sensors !

New method for detecting life in boreholes - DEBI-t

Deep Exploration Biosphere Investigative tool

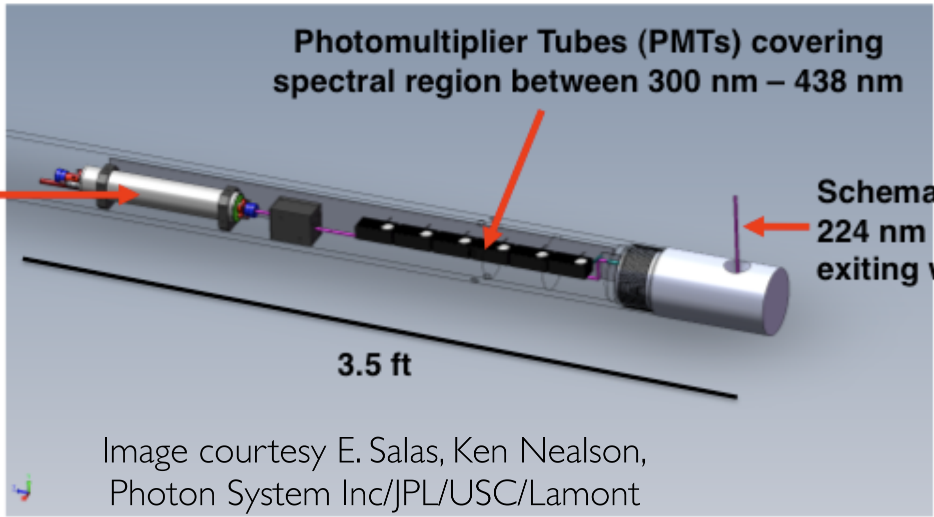
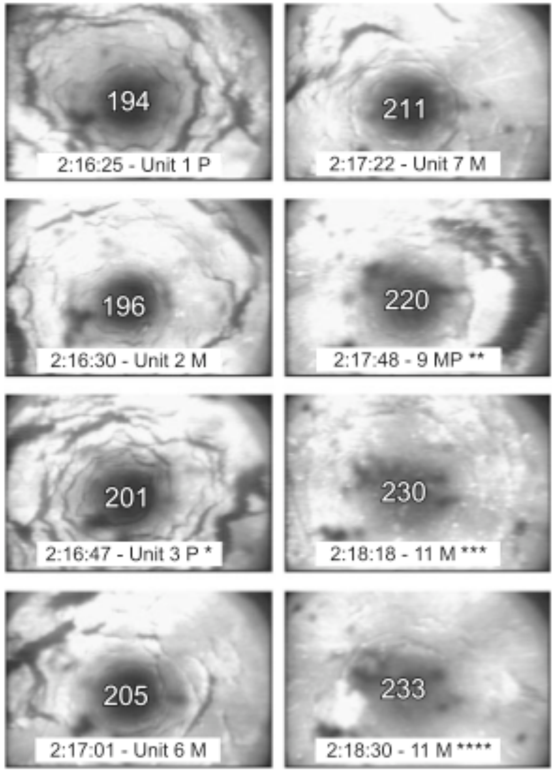


Image courtesy E. Salas, Ken Nealson, Photon System Inc/JPL/USC/Lamont



Borehole photographs taken at Hole 896A
Becker et al. 2004

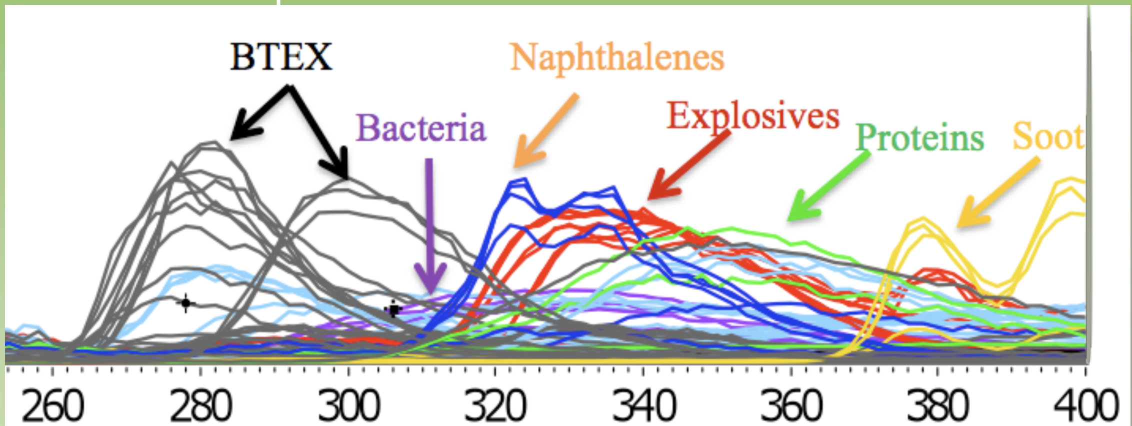
A new wireline logging tool for imaging borehole and conducting deep UV scanning

Images courtesy Ken Nealson (USC)

DEBI-t principles

New method for detecting life - Deep UV spectroscopy and imaging

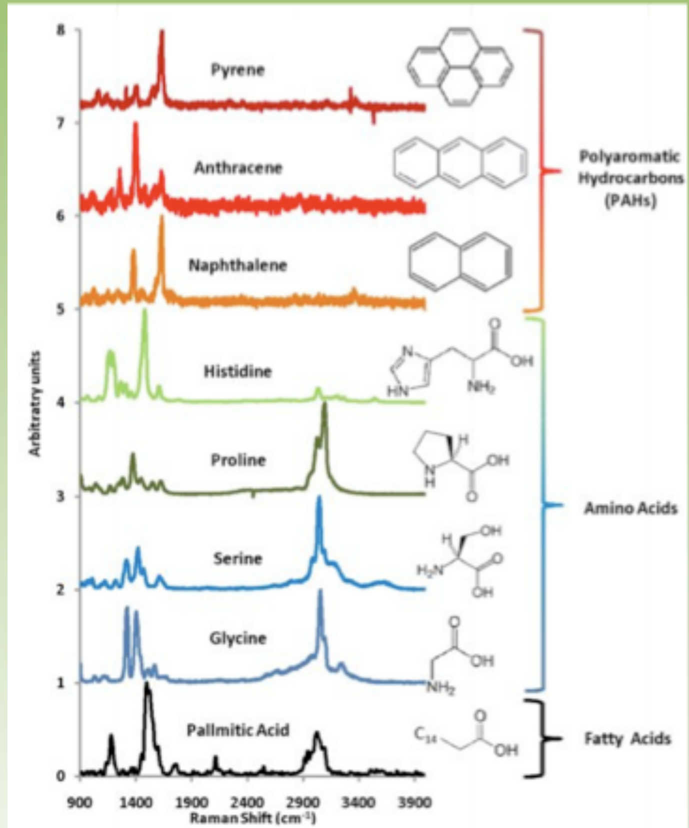
Deep UV - Excitation: 224 nm



Emission Wavelength (nm)

Deep UV native fluorescence and Raman shifts of biological materials can be used to screen samples for life = “chemometrics”

Deep UV Raman



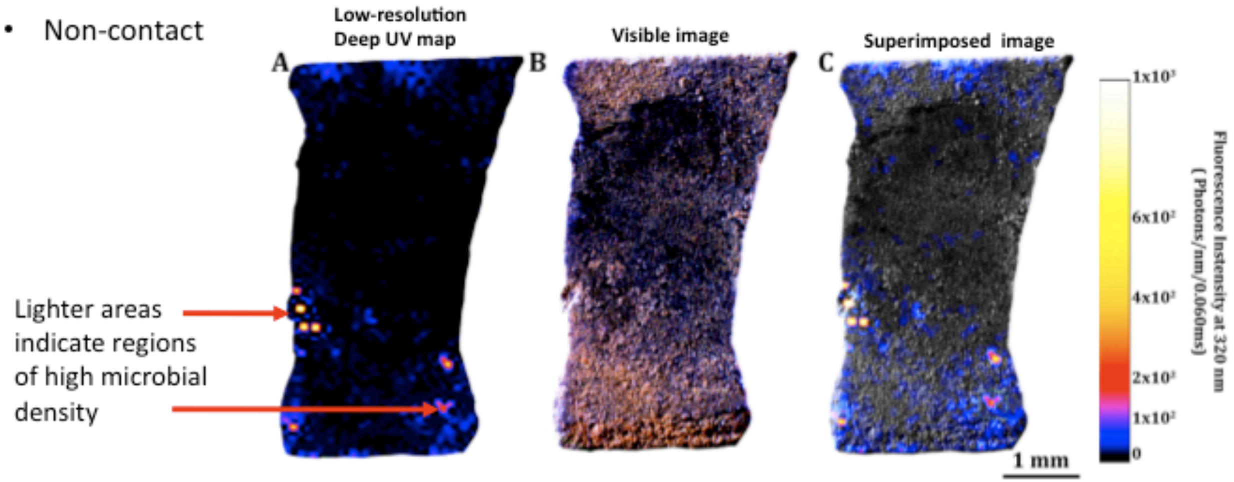
Images courtesy Ken Nealson (USC)

DEBI-t principles

New method for detecting life - Deep UV spectroscopy and imaging

- Excitation below 250nm
- Label-free (no stains, antibodies, etc)
- Rapid
- Non-contact

Sample from the Lohi'i Seamount

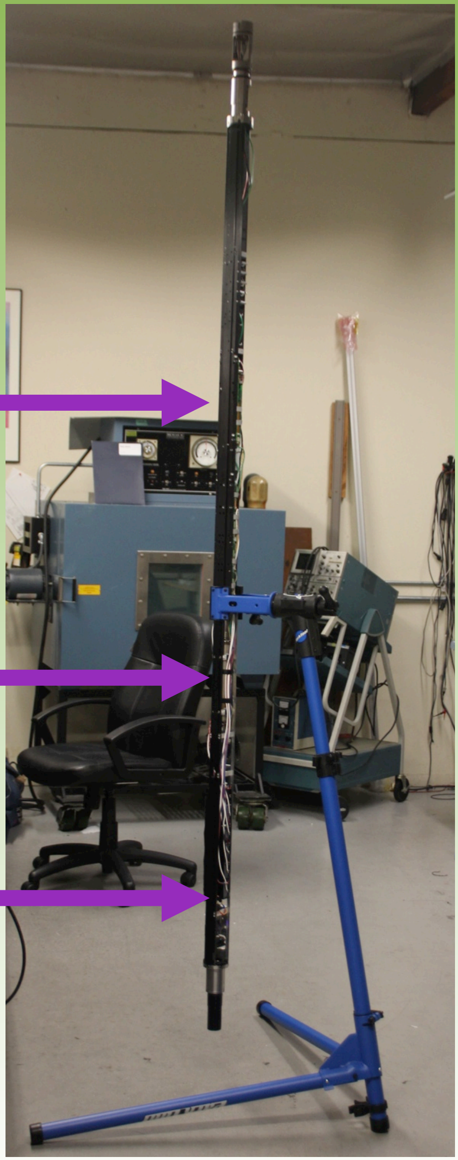


Detection of cells on mineral chips incubated at Loihi Seamount

Bhartia et al., AEM 2010

Current DEBI-t design

Logging tool used on IODP X336



<u>Uphole connector</u>

31-pin Schlumberger connector

<u>Control & Communications</u>

'Fire & forget' methodolgy

Communications via LDEO MFTM

3-axis downhole acceleration

<u>Deep UV laser source</u>

224 nm HeAg hollow cathode laser

<u>Collection optics</u>

7-channel detection system

High-definition pin-hole camera

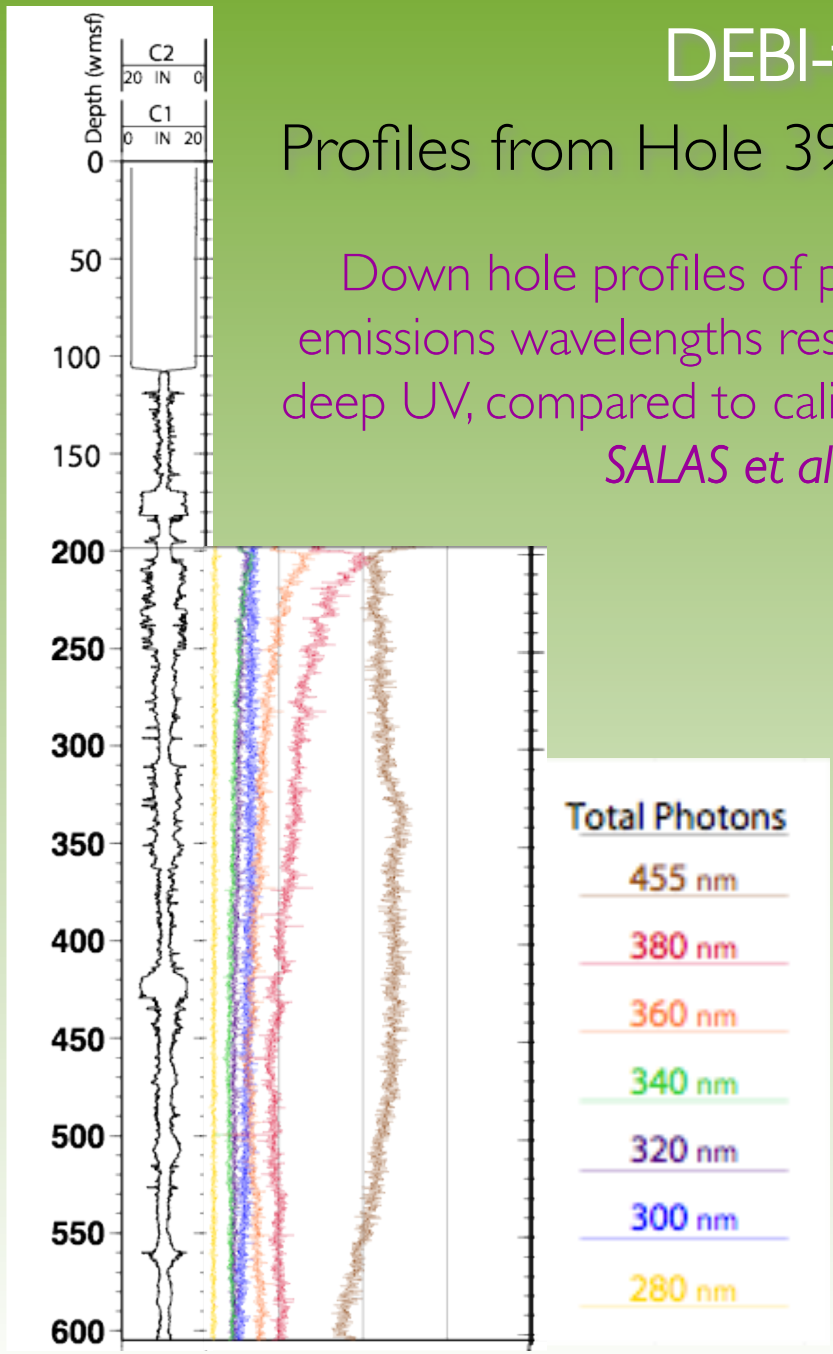
JPL
NASA
LDEO
Photon Systems

DEBI-t results

Profiles from Hole 395A after removing CORK

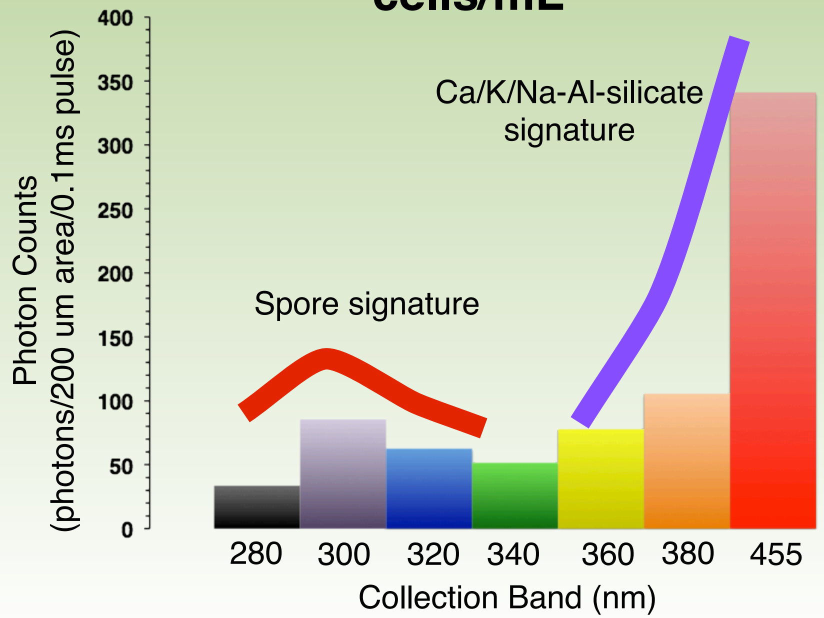
JPL
NASA
LDEO
Photon Systems

Down hole profiles of photon counts of specific emissions wavelengths resulting from excitation with deep UV, compared to caliper log from the boreholes
SALAS et al. IN REVIEW



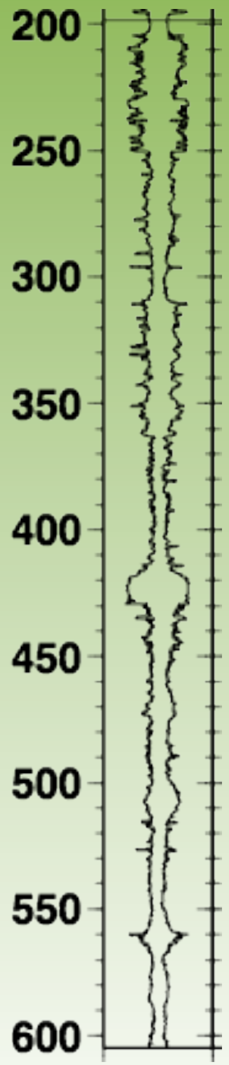
Hole 395A contains spore-like signals

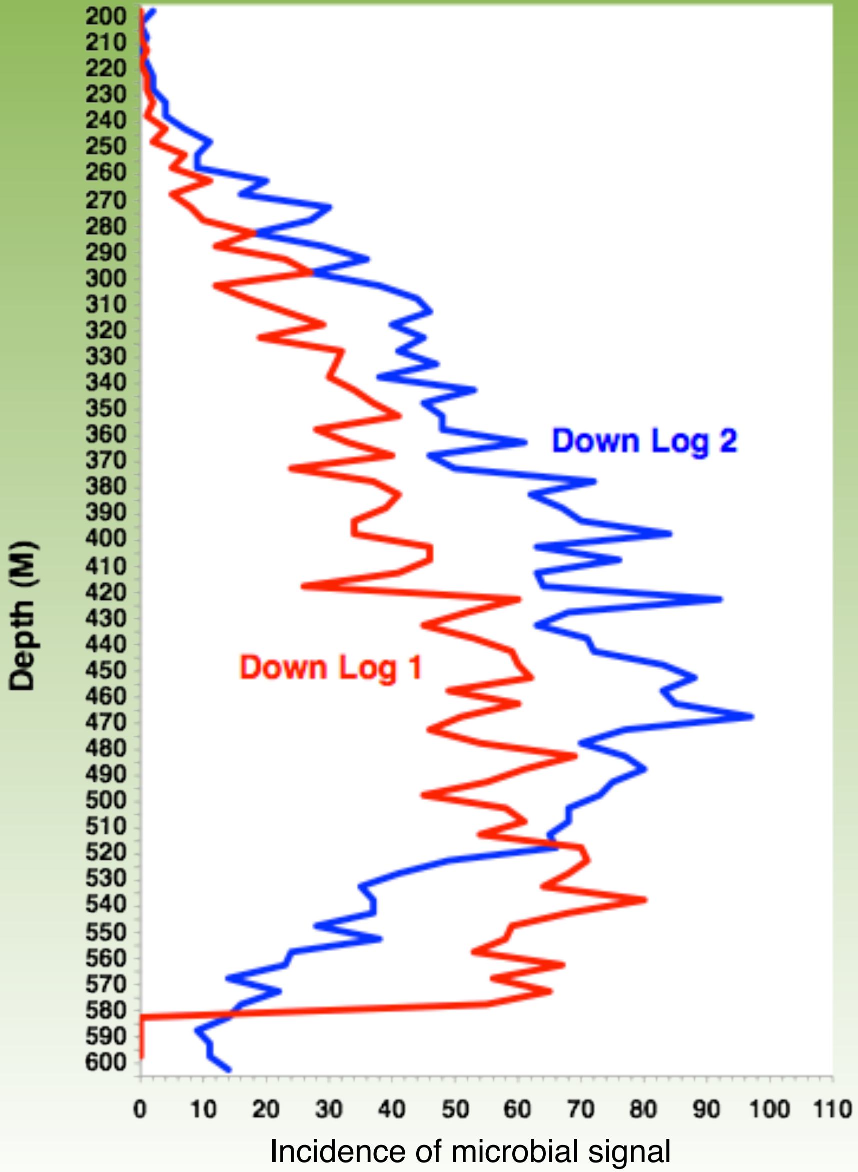
Microbial intensity correlates to ~10^6 cells/mL



DEBI-t results

Profiles from Hole 395A after removing CORK





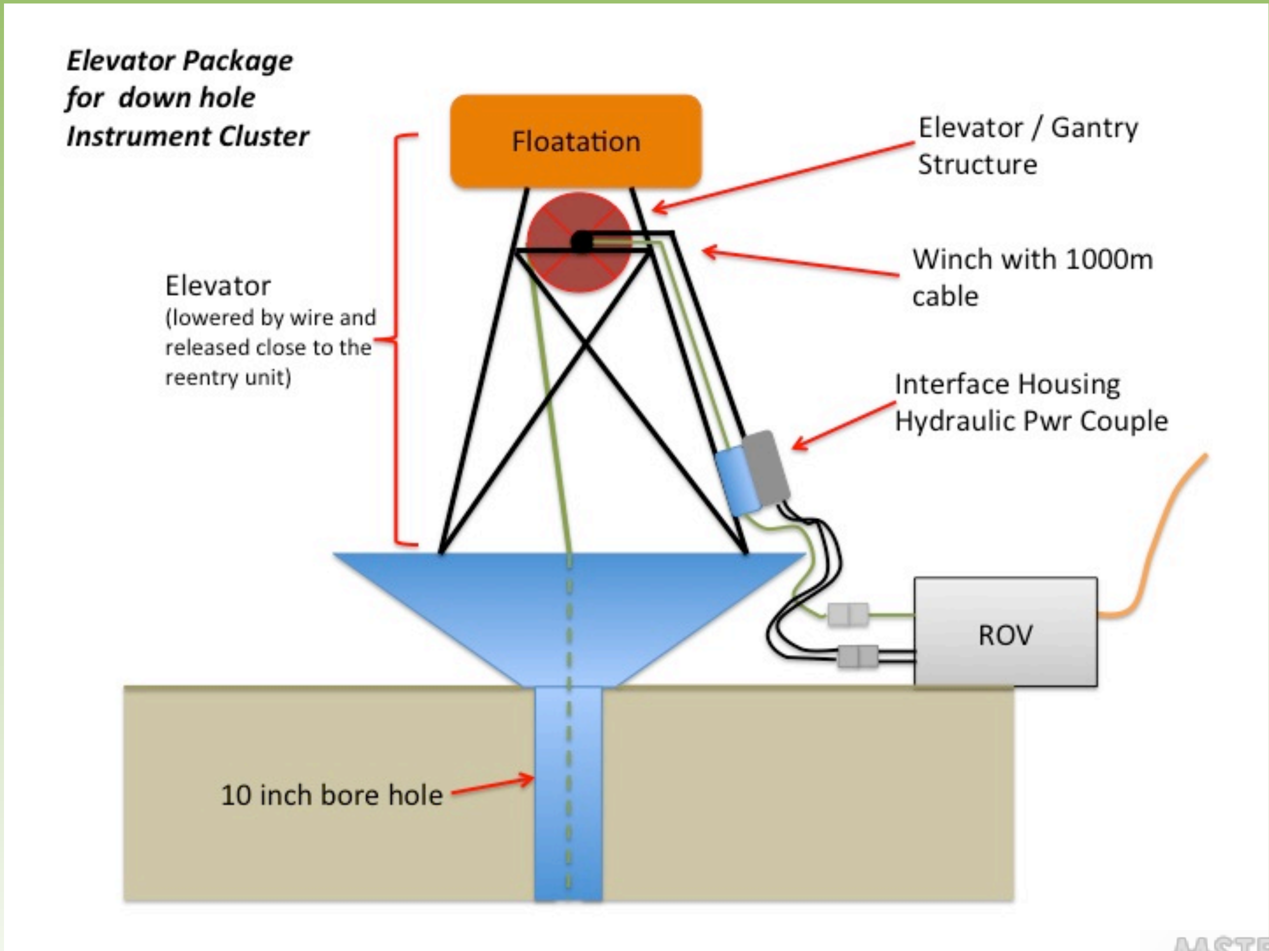
Frequency of microbial "hits" increases downhole

SALAS et al. IN REVIEW

JPL
NASA
LDEO
Photon Systems

Future – Refining sensors for logging legacy boreholes

Two phases – logging legacy holes,
then making new observatories at legacy holes with CORK-Light



Phase I

Updating DEBI-t to DEBI-SELECT *(better camera, more sensors)* - Wheat & Edwards w/ Photon Systems

Miniaturizing electrochemical sensors – Brian Glazer

Designing new logging system

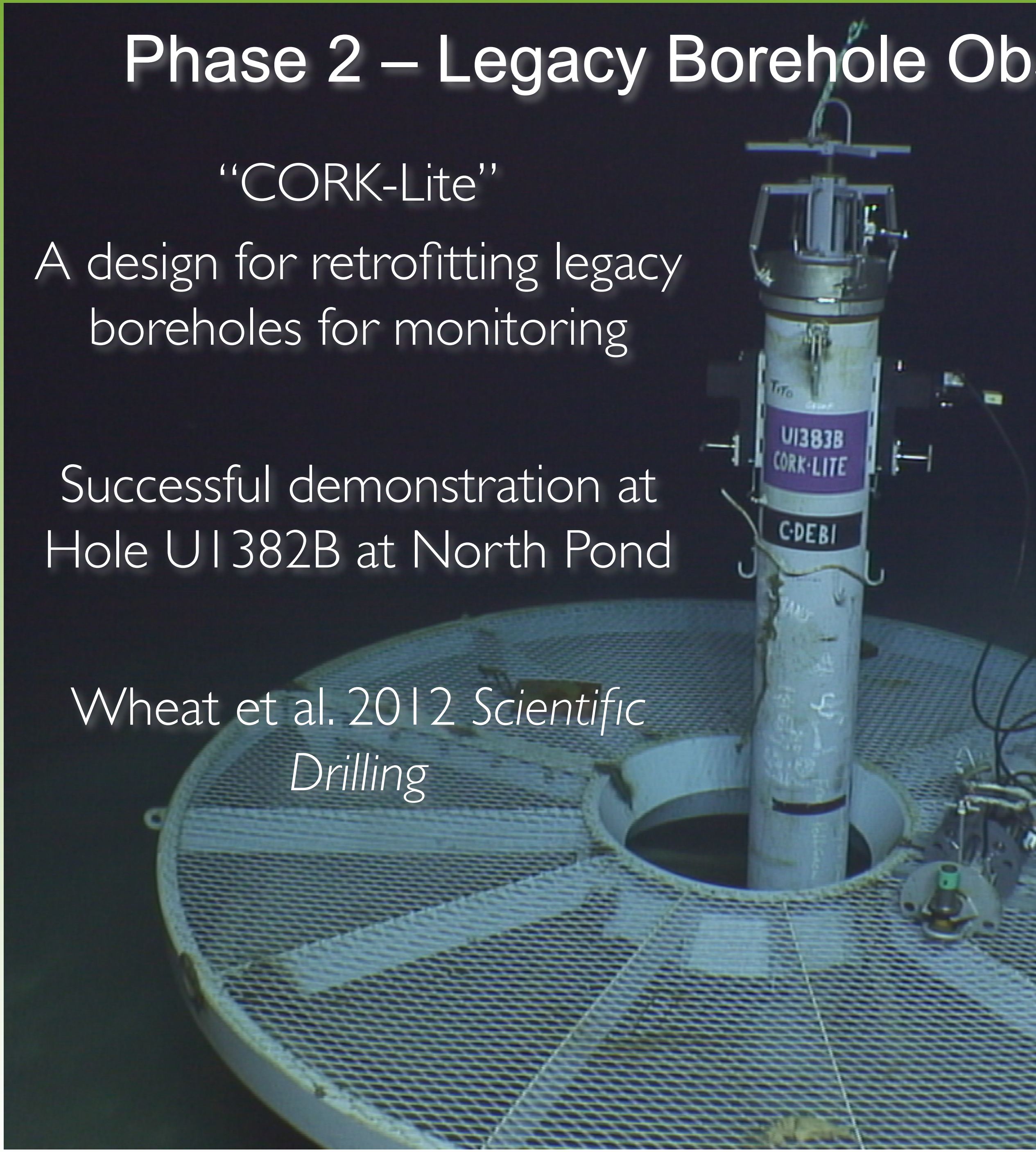
Phase 2 – Legacy Borehole Observatories

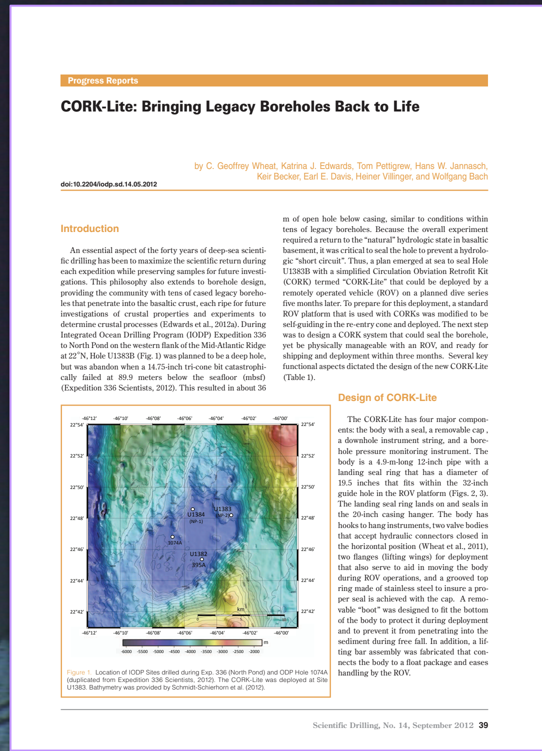
"CORK-Lite"

A design for retrofitting legacy boreholes for monitoring

Successful demonstration at Hole U1382B at North Pond

Wheat et al. 2012 *Scientific Drilling*





Progress Reports

CORK-Lite: Bringing Legacy Boreholes Back to Life

by C. Geoffrey Wheat, Katrina J. Edwards, Tom Pettigrew, Hans W. Jannasch, Keir Becker, Earl E. Davis, Heiner Villinger, and Wolfgang Bach

doi:10.2204/iodp.sd.14.05.2012

Introduction

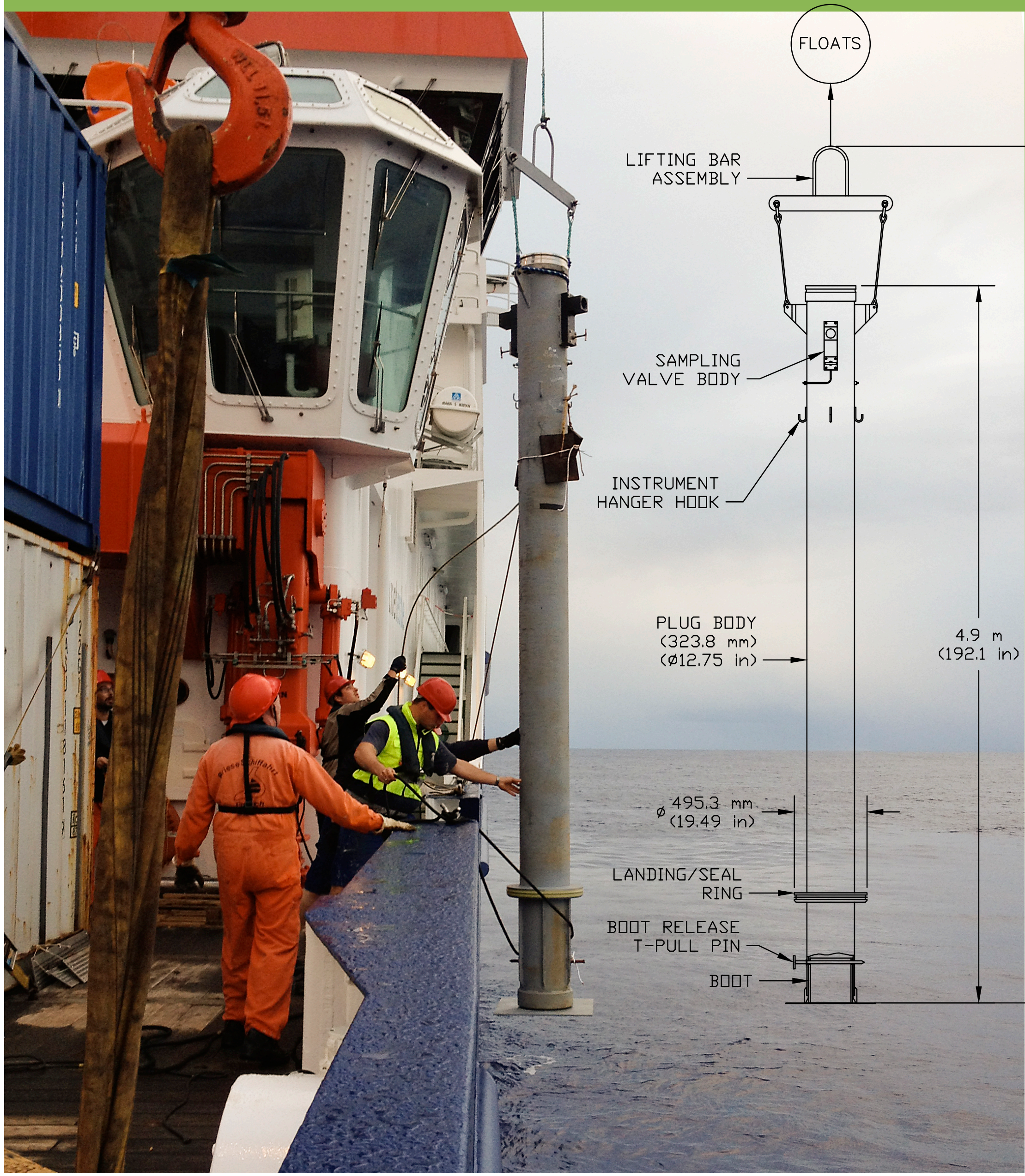
An essential aspect of the forty years of deep-sea scientific drilling has been to maximize the scientific return during each expedition while preserving samples for future investigations. This philosophy also extends to borehole design, providing the community with tens of cased legacy boreholes that penetrate into the basaltic crust, each ripe for future investigations of crustal properties and experiments to determine crustal processes (Edwards et al., 2012a). During Integrated Ocean Drilling Program (IODP) Expedition 336 to North Pond on the western flank of the Mid-Atlantic Ridge at 22°N, Hole U1383B (Fig. 1) was planned to be a deep hole, but was abandon when a 14.75-inch tri-cone bit catastrophically failed at 89.9 meters below the seafloor (mbsf) (Expedition 336 Scientists, 2012). This resulted in about 36 m of open hole below casing, similar to conditions within tens of legacy boreholes. Because the overall experiment required a return to the "natural" hydrologic state in basaltic basement, it was critical to seal the hole to prevent a hydrologic "short circuit". Thus, a plan emerged at sea to seal Hole U1383B with a simplified Circulation Obviation Retrofit Kit (CORK) termed "CORK-Lite" that could be deployed by a remotely operated vehicle (ROV) on a planned dive series five months later. To prepare for this deployment, a standard ROV platform that is used with CORKs was modified to be self-guiding in the re-entry cone and deployed. The next step was to design a CORK system that could seal the borehole, yet be physically manageable with an ROV, and ready for shipping and deployment within three months. Several key functional aspects dictated the design of the new CORK-Lite (Table 1).

Figure 1. Location of IODP Sites drilled during Exp. 336 (North Pond) and ODP Hole 1074A (duplicated from Expedition 336 Scientists, 2012). The CORK-Lite was deployed at Site U1383. Bathymetry was provided by Schmidt-Schierhorn et al. (2012).

Design of CORK-Lite

The CORK-Lite has four major components: the body with a seal, a removable cap , a downhole instrument string, and a borehole pressure monitoring instrument. The body is a 4.9-m-long 12-inch pipe with a landing seal ring that has a diameter of 19.5 inches that fits within the 32-inch guide hole in the ROV platform (Figs. 2, 3). The landing seal ring lands on and seals in the 20-inch casing hanger. The body has hooks to hang instruments, two valve bodies that accept hydraulic connectors closed in the horizontal position (Wheat et al., 2011), two flanges (lifting wings) for deployment that also serve to aid in moving the body during ROV operations, and a grooved top ring made of stainless steel to insure a proper seal is achieved with the cap. A removable "boot" was designed to fit the bottom of the body to protect it during deployment and to prevent it from penetrating into the sediment during free fall. In addition, a lifting bar assembly was fabricated that connects the body to a float package and eases handling by the ROV.

Phase 2 – Legacy Borehole Observatories



OsmoSampler package hangs inside the CORK-Lite to sample fluids

Phase 2 – Legacy Borehole Observatories

CORK-Lite versus Multi-level CORK

Item	CORK	CORK-Lite
ROV cone	$34,000	$34,000
"16 hardware	$90,000	$90,000
60 m		
"10.75" hardware	$66,000	$66,000
250 m		
4.5" hardware	$71,000	
Umbilicals	$335,000	
parts	$52,000	
Well Head	$40,000	
Packers	$240,000	
	$928,000	**$190,000**
pressure	$50,000	$43,000
temperaature	$9,000	$5,000
engineering/body		$30,000
OmoSamplers	$170,000	$70,000
hardware	$20,000	$5,000
top plug	$5,000	
	$254,000	**$153,000**
TOTAL	**$1,182,000**	**$343,000**